APPENDIX C TO PART 213[RESERVED]

APPENDIX D TO PART 213—MINIMALLY COMPLIANT ANALYTICAL TRACK (MCAT) SIMULATIONS USED FOR QUALIFYING VEHICLES TO OPERATE AT HIGH SPEEDS AND AT HIGH CANT DEFICIENCIES

1. This appendix contains requirements for using computer simulations to comply with the vehicle/track system qualification testing requirements specified in subpart G of this part. These simulations shall be performed using a track model containing defined geometry perturbations at the limits that are permitted for a specific class of track and level of cant deficiency. This track model is known as MCAT, Minimally Compliant Analytical Track. These simulations shall be used to identify vehicle dynamic performance issues prior to service or, as appropriate, a change in service, and demonstrate that a vehicle type is suitable for operation on the track over which it is intended to operate.

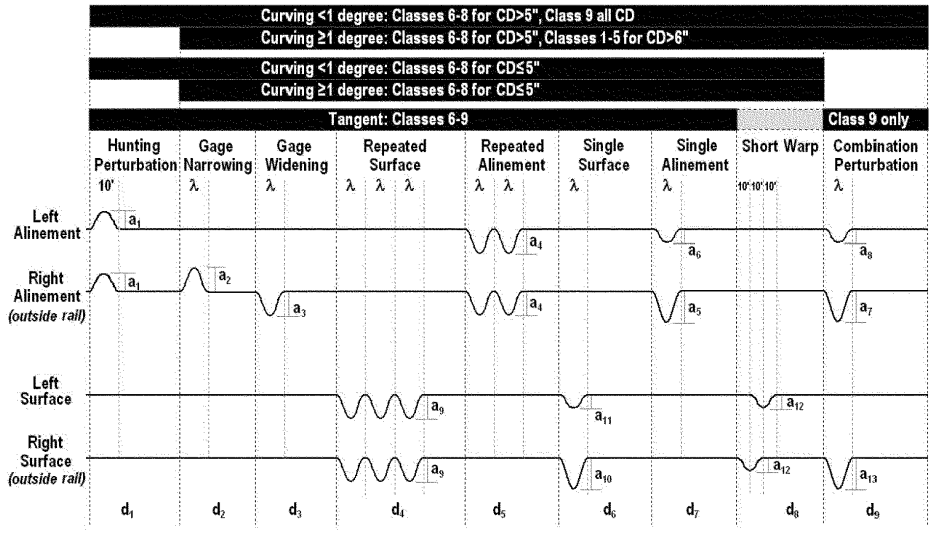
2. As specified in §213.345(c)(2), MCAT shall be used for the qualification of new vehicle types intended to operate at track Class 7 speeds or above, or at any curving speed producing more than 6 inches of cant deficiency. MCAT may also be used for the qualification of new vehicle types intended to operate at speeds corresponding to Class 6 track, as specified in §213.345(c)(1). In addition, as specified in §213.345(d)(1), MCAT may be used to qualify on new routes vehicle types that have previously been qualified on other routes and are intended to operate at any curving speed producing more than 6 inches of cant deficiency, or at curving speeds that both correspond to track Class 7 speeds or above and produce more than 5 inches of cant deficiency.

(a) *Validation.* To validate the vehicle model used for simulations under this part, the track owner or railroad shall obtain vehicle simulation predictions using measured track geometry data, chosen from the same track section over which testing shall be performed as specified in §213.345(c)(2)(ii). These predictions shall be submitted to FRA in support of the request for approval of the qualification testing plan. Full validation of the vehicle model used for simulations under this part shall be determined when the results of the simulations demonstrate that they replicate all key responses observed during qualification testing.

(b) *MCAT layout.* MCAT consists of nine segments, each designed to test a vehicle's performance in response to a specific type of track perturbation. The basic layout of MCAT is shown in figure 1 of this appendix, by type of track (curving or tangent), class of track, and cant deficiency (CD). The values for wavelength, λ, amplitude of perturbation, a, and segment length, d, are specified in this appendix. The bars at the top of figure 1 show which segments are required depending on the speed and degree of curvature. For example, the hunting perturbation section is not required for simulation of curves greater than or equal to 1 degree.

Figure 1 of Appendix D to Part 213

Basic MCAT Layout



(1) *MCAT segments.* MCAT's nine segments contain different types of track deviations in which the shape of each deviation is a versine having wavelength and amplitude varied for each simulation speed as further specified. The nine MCAT segments are defined as follows:

(i) *Hunting perturbation* (a_1): This segment contains an alinement deviation having a wavelength, λ, of 10 feet and amplitude of 0.25 inch on both rails to test vehicle stability on tangent track and on track that is curved less than 1 degree.

(ii) *Gage narrowing* (a_2): This segment contains an alinement deviation on one rail to reduce the gage from the nominal value to the minimum permissible gage or maximum alinement (whichever comes first).

(iii) *Gage widening* (a_3): This segment contains an alinement deviation on one rail to increase the gage from the nominal value to the maximum permissible gage or maximum alinement (whichever comes first).

(iv) *Repeated surface* (a_9): This segment contains three consecutive maximum permissible profile variations on each rail.

(v) *Repeated alinement* (a_4): This segment contains two consecutive maximum permissible alinement variations on each rail.

(vi) *Single surface* (a_{10}, a_{11}): This segment contains a maximum permissible profile variation on one rail. If the maximum permissible profile variation alone produces a condition which exceeds the maximum allowed warp condition, a second profile variation is also placed on the opposite rail to limit the warp to the maximum permissible value.

(vii) *Single alinement* (a_5, a_6): This segment contains a maximum permissible alinement variation on one rail. If the maximum permissible alinement variation alone produces a condition which exceeds the maximum allowed gage condition, a second alinement variation is also placed on the opposite rail to limit the gage to the maximum permissible value.

(viii) *Short warp* (a_{12}): This segment contains a pair of profile deviations to produce a maximum permissible 10-foot warp perturbation. The first is on the outside rail, and the second follows 10 feet farther on the inside rail. Each deviation has a wavelength, λ, of 20 feet and variable amplitude for each simulation speed as described below. This segment is to be used only on curved track simulations.

(ix) *Combined perturbation* (a_7, a_8, a_{13}): This segment contains a maximum permissible down and out combined geometry condition on the outside rail in the body of the curve. If the maximum permissible variations produce a condition which exceeds the maximum allowed gage condition, a second variation is also placed on the opposite rail as for the MCAT segments described in paragraphs (b)(1)(vi) and (vii) of this appendix.

This segment is to be used for all simulations on Class 9 track, and only for curved track simulations at speeds producing more than 5 inches of cant deficiency on track Classes 6 through 8, and at speeds producing more than 6 inches of cant deficiency on track Classes 1 through 5.

(2) *Segment lengths:* Each MCAT segment shall be long enough to allow the vehicle's response to the track deviation(s) to damp out. Each segment shall also have a minimum length as specified in table 1 of this appendix, which references the distances in figure 1 of this appendix. For curved track segments, the perturbations shall be placed far enough in the body of the curve to allow for any spiral effects to damp out.

TABLE 1 OF APPENDIX D TO PART 213 MINIMUM LENGTHS OF MCAT SEGMENTS

Distances (ft)								
d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9
1000	1000	1000	1500	1000	1000	1000	1000	1000

(3) *Degree of curvature.*

(i) For each simulation involving assessment of curving performance, the degree of curvature, D, which generates a particular level of cant deficiency, E_u, for a given speed, V, shall be calculated using the following equation, which assumes a curve with 6 inches of superelevation:

$$D = \frac{6 + E_u}{0.0007 \times V^2}$$

Where—

D = Degree of curvature (degrees).
V = Simulation speed (m.p.h.).
E_u = Cant deficiency (inches).

(ii) Table 2 of this appendix depicts the degree of curvature for use in MCAT simulations of both passenger and freight equipment performance on Class 2 through 9 track, based on the equation in paragraph (b)(3)(i) of this appendix. The degree of curvature for use in MCAT simulations of equipment performance on Class 1 track is not depicted; it would be based on the same equation using an appropriate superelevation. The degree of curvature for use in MCAT simulations of freight equipment performance on Class 6 (freight) track is shown in italics for cant deficiencies not exceeding 6 inches, to emphasize that the values apply to freight equipment only.

Table 2 of Appendix D to Part 213
Degree of Curvature for Use in MCAT Simulations (Track Classes 2 through 9)

		Tangent	Cant Deficiency (inches)								
			3	4	5	6	7	8	9		
Passenger	m.p.h.	Degree of curvature used in simulations								m.p.h.	Freight
Class 2	20						46.4	50.0	53.6	20	Class 2
	25						29.7	32.0	34.3	25	
	30						20.6	22.2	23.8	30	Class 3
Class 3	35						15.2	16.3	17.5	35	
	40						11.6	12.5	13.4	40	
	45						9.17	9.88	10.6	45	Class 4
	50						7.43	8.00	8.57	50	
	55						6.14	6.61	7.08	55	
	60						5.16	5.56	5.95	60	
Class 4	65						4.40	4.73	5.07	65	Class 5
	70						3.79	4.08	4.37	70	
	75						3.30	3.56	3.81	75	
	80						2.90	3.13	3.35	80	
Class 5	85	*0.00*	*1.78*	*1.98*	*2.18*	*2.37*	2.57	2.77	2.97	85	Class 6
	90	*0.00*	*1.59*	*1.76*	*1.94*	*2.12*	2.29	2.47	2.65	90	
Class 6	95	0.00	1.42	1.58	1.74	1.90	2.06	2.22	2.37	95	
	100	0.00	1.29	1.43	1.57	1.71	1.86	2.00	2.14	100	
	105	0.00	1.17	1.30	1.43	1.55	1.68	1.81	1.94	105	
	110	0.00	1.06	1.18	1.30	1.42	1.53	1.65	1.77	110	
Class 7	115	0.00	0.97	1.08	1.19	1.30	1.40	1.51	1.62	115	Class 7
	120	0.00	0.89	0.99	1.09	1.19	1.29	1.39	1.49	120	
	125	0.00	0.82	0.91	1.01	1.10	1.19	1.28	1.37	125	
Class 8	130	0.00	0.76	0.85	0.93	1.01	1.10	1.18	1.27	130	Class 8
	135	0.00	0.71	0.78	0.86	0.94	1.02	1.10	1.18	135	
	140	0.00	0.66	0.73	0.80	0.87	0.95	1.02	1.09	140	
	145	0.00	0.61	0.68	0.75	0.82	0.88	0.95	1.02	145	
	150	0.00	0.57	0.63	0.70	0.76	0.83	0.89	0.95	150	
	155	0.00	0.54	0.59	0.65	0.71	0.77	0.83	0.89	155	
	160	0.00	0.50	0.56	0.61	0.67	0.73	0.78	0.84	160	
Class 9	165	0.00	0.47	0.52	0.58	0.63	0.68	0.73	0.79	165	Class 9
	170	0.00	0.44	0.49	0.54	0.59	0.64	0.69	0.74	170	
	175	0.00	0.42	0.47	0.51	0.56	0.61	0.65	0.70	175	
	180	0.00	0.40	0.44	0.49	0.53	0.57	0.62	0.66	180	
	185	0.00	0.38	0.42	0.46	0.50	0.54	0.58	0.63	185	
	190	0.00	0.36	0.40	0.44	0.47	0.51	0.55	0.59	190	
	195	0.00	0.34	0.38	0.41	0.45	0.49	0.53	0.56	195	
	200	0.00	0.32	0.36	0.39	0.43	0.46	0.50	0.54	200	
	205	0.00	0.31	0.34	0.37	0.41	0.44	0.48	0.51	205	
	210	0.00	0.29	0.32	0.36	0.39	0.42	0.45	0.49	210	
	215	0.00	0.28	0.31	0.34	0.37	0.40	0.43	0.46	215	
	220	0.00	0.27	0.30	0.32	0.35	0.38	0.41	0.44	220	

(c) *Required simulations.*

(1) To develop a comprehensive assessment of vehicle performance, simulations shall be performed for a variety of scenarios using MCAT. These simulations shall be performed on tangent or curved track, or both, depending on the level of cant deficiency and speed (track class) as summarized in table 3 of this appendix.

TABLE 3 OF APPENDIX D TO PART 213 SUMMARY OF REQUIRED VEHICLE PERFORMANCE ASSESSMENT USING SIMULATIONS

	New vehicle types	Previously qualified vehicle types
Curved track: cant deficiency ≤6 inches.	Curving performance simulation: not required for track Classes 1 through 5; optional for track Class 6; required for track Classes 7 through 9.	Curving performance simulation: not required for track Classes 1 through 6; optional for track Classes 7 through 9 for cant deficiency >5 inches.
Curved track: cant deficiency >6 inches.	Curving performance simulation required for all track classes.	Curving performance simulation optional for all track classes.
Tangent track	Tangent performance simulation: not required for track Classes 1 through 5; optional for track Class 6; required for track Classes 7 through 9.	Tangent performance simulation not required for any track class.

(i) All simulations shall be performed using the design wheel profile and a nominal track gage of 56.5 inches, using tables 4, 5, 6, or 7 of this appendix, as appropriate. In addition, all simulations involving the assessment of curving performance shall be repeated using a nominal track gage of 57.0 inches, using tables 5, 6, or 7 of this appendix, as appropriate.

(ii) If the wheel profile is different than American Public Transportation Administration (APTA) wheel profiles 320 or 340, then for tangent track segments all simulations shall be repeated using either APTA wheel profile 320 or 340, depending on the established conicity that is common for the operation, as specified in APTA SS–M–015–06, Standard for Wheel Flange Angle of Passenger Equipment (2007). This APTA standard is incorporated by reference into this appendix with the approval of the Director of the Federal Register under 5 U.S.C. 552(a) and 1 CFR part 51. To enforce any edition other than that specified in this appendix, FRA must publish notice of change in the FEDERAL REGISTER and the material must be made available to the public. All approved material is available for inspection at the Federal Railroad Administration, Docket Clerk, 1200 New Jersey Avenue SE., Washington, DC 20590 (telephone 202–493–6030), and is available from the American Public Transportation Association, 1666 K Street NW., Suite 1100, Washington, DC 20006 (telephone 202–496–4800; *www.apta.com*). It is also available for inspection at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202–741–6030 or go to *http://www.archives.gov/federal_register/code_of_federal_regulations/ibr_locations.html*. An alternative worn wheel profile may be used in lieu of either APTA wheel profile, if approved by FRA.

(iii) All simulations shall be performed using a wheel/rail coefficient of friction of 0.5.

(2) *Vehicle performance on tangent track Classes 6 through 9.* For maximum vehicle speeds corresponding to track Class 6 and higher, the MCAT segments described in paragraphs (b)(1)(i) through (vii) of this appendix shall be used to assess vehicle performance on tangent track. For track Class 9, simulations must also include the combined perturbation segment described in paragraph (b)(1)(ix) of this appendix. A parametric matrix of MCAT simulations shall be performed using the following range of conditions:

(i) *Vehicle speed.* Simulations shall demonstrate that at up to 5 m.p.h. above the proposed maximum operating speed, the vehicle type shall not exceed the wheel/rail force and acceleration criteria defined in the Vehicle/Track Interaction Safety Limits table in §213.333. Simulations shall also demonstrate acceptable vehicle dynamic response by incrementally increasing speed from 95 m.p.h. (115 m.p.h. if a previously qualified vehicle type on an untested route) to 5 m.p.h. above the proposed maximum operating speed (in 5 m.p.h. increments).

(ii) *Perturbation wavelength.* For each speed, a set of three separate MCAT simulations shall be performed. In each MCAT simulation for the perturbation segments described in paragraphs (b)(1)(ii) through (vii) and (b)(1)(ix) of this appendix, every perturbation shall have the same wavelength. The following three wavelengths, λ, shall be used: 31, 62, and 124 feet. The hunting perturbation segment described in paragraph (b)(1)(i) of this appendix has a fixed wavelength, λ, of 10 feet.

(iii) *Amplitude parameters.* Table 4 of this appendix provides the amplitude values for the MCAT segments described in paragraphs (b)(1)(i) through (vii) and (b)(1)(ix) of this appendix for each speed of the required parametric MCAT simulations. The last set of simulations shall be performed at 5 m.p.h. above the proposed maximum operating speed using the amplitude values in table 4 that correspond to the proposed maximum operating speed. For qualification of vehicle types at speeds greater than track Class 6 speeds, the following additional simulations shall be performed:

(A) For vehicle types being qualified for track Class 7 speeds, one additional set of simulations shall be performed at 115 m.p.h. using the track Class 6 amplitude values in table 4 (i.e., a 5 m.p.h. overspeed on Class 6 track).

(B) For vehicle types being qualified for track Class 8 speeds, two additional sets of simulations shall be performed. The first set at 115 m.p.h. using the track Class 6 amplitude values in table 4 (i.e., a 5 m.p.h. overspeed on Class 6 track), and a second set at 130 m.p.h. using the track Class 7 amplitude values in table 4 (i.e., a 5 m.p.h. overspeed on Class 7 track).

(C) For vehicle types being qualified for track Class 9 speeds, three additional sets of simulations shall be performed. The first set at 115 m.p.h. using the track Class 6 amplitude values in table 4 (i.e., a 5 m.p.h. overspeed on Class 6 track), a second set at 130 m.p.h. using the track Class 7 amplitude values in table 4 (i.e., a 5 m.p.h. overspeed on Class 7 track), and a third set at 165 m.p.h. using the track Class 8 amplitude values in table 4 (i.e., a 5 m.p.h. overspeed on Class 8 track).

Table 4 of Appendix D to Part 213
Track Class 6 through 9 Amplitude Parameters (in inches)
for MCAT Simulations on Tangent Track

		Gage 56.5"			
		Class 6	Class 7	Class 8	Class 9
Max. Operating Speed (m.p.h.)		110	125	160	220
Max. Simulation Speed (m.p.h.)		115	130	165	225
MCAT Segments	**Parameter**	**Segment Description**			
Hunting	a_1	(b)(1)(i)			
Gage Narrowing	a_2	(b)(1)(ii)			
Gage Widening	a_3	(b)(1)(iii)			
Repeated Surface	a_9	(b)(1)(iv)			
Repeated Alinement	a_4	(b)(1)(v)			
Single Surface	a_{10}, a_{11}	(b)(1)(vi)			
Single Alinement	a_5, a_6	(b)(1)(vii)			
Short Warp	a_{12}				
Combined Perturbation	a_7, a_8, a_{13}				(b)(1)(ix)
		Amplitude Parameters (inches)			
Wavelength λ = 10ft	a_1	0.250	0.250	0.250	0.250
Wavelength λ = 20ft	a_{12}				
Wavelength λ = 31ft	a_2	0.500	0.500	0.500	0.250
	a_3	0.750	0.500	0.500	0.500
	a_4	0.375	0.375	0.375	0.375
	a_5	0.500	0.500	0.500	0.500
	a_6	0.000	0.000	0.000	0.000
	a_7				0.333
	a_8				0.000
	a_9	0.750	0.750	0.500	0.375
	a_{10}	1.000	1.000	0.750	0.500
	a_{11}	0.000	0.000	0.000	0.000
	a_{13}				0.333
Wavelength λ = 62ft	a_2	0.500	0.500	0.500	0.250
	a_3	0.750	0.500	0.500	0.500
	a_4	0.500	0.375	0.375	0.375
	a_5	0.750	0.750	0.750	0.500
	a_6	0.000	0.250	0.250	0.000
	a_7				0.333
	a_8				0.000
	a_9	0.750	0.750	0.750	0.500
	a_{10}	1.000	1.000	1.000	0.750
	a_{11}	0.000	0.000	0.000	0.000
	a_{13}				0.500
Wavelength λ = 124ft	a_2	0.500	0.500	0.500	0.250
	a_3	0.750	0.750	0.750	0.750
	a_4	1.000	0.875	0.500	0.500
	a_5	1.500	1.250	1.000	0.750
	a_6	0.750	0.500	0.250	0.000
	a_7				0.500
	a_8				0.000
	a_9	1.250	1.000	0.875	0.625
	a_{10}	1.750	1.500	1.250	1.000
	a_{11}	0.250	0.000	0.000	0.000
	a_{13}				0.667

(3) *Vehicle performance on curved track Classes 6 through 9.* For maximum vehicle speeds corresponding to track Class 6 and higher, the MCAT segments described in paragraphs (b)(1)(ii) through (viii) of this appendix shall be used to assess vehicle performance on curved track. For curves less than 1 degree, simulations must also include

the hunting perturbation segment described in paragraph (b)(1)(i) of this appendix. For track Class 9 and for cant deficiencies greater than 5 inches, simulations must also include the combined perturbation segment described in paragraph (b)(1)(ix) of this appendix. A parametric matrix of MCAT simulations shall be performed using the following range of conditions:

(i) *Vehicle speed.* Simulations shall demonstrate that at up to 5 m.p.h. above the proposed maximum operating speed, the vehicle type shall not exceed the wheel/rail force and acceleration criteria defined in the Vehicle/Track Interaction Safety Limits table in §213.333. Simulations shall also demonstrate acceptable vehicle dynamic response by incrementally increasing speed from 95 m.p.h. (115 m.p.h. if a previously qualified vehicle type on an untested route) to 5 m.p.h. above the proposed maximum operating speed (in 5 m.p.h. increments).

(ii) *Perturbation wavelength.* For each speed, a set of three separate MCAT simulations shall be performed. In each MCAT simulation for the perturbation segments described in paragraphs (b)(1)(ii) through (vii) and paragraph (b)(1)(ix) of this appendix, every perturbation shall have the same wavelength. The following three wavelengths, λ, shall be used: 31, 62, and 124 feet. The hunting perturbation segment described in paragraph (b)(1)(i) of this appendix has a fixed wavelength, λ, of 10 feet, and the short warp perturbation segment described in paragraph (b)(1)(viii) of this appendix has a fixed wavelength, λ, of 20 feet.

(iii) *Track curvature.* For each speed, a range of curvatures shall be used to produce cant deficiency conditions ranging from greater than 3 inches up to the maximum intended for qualification (in 1 inch increments). The value of curvature, D, shall be determined using the equation defined in paragraph (b)(3) of this appendix. Each curve shall include representations of the MCAT segments described in paragraphs (b)(1)(i) through (ix) of this appendix, as appropriate, and have a fixed superelevation of 6 inches.

(iv) *Amplitude parameters.* Table 5 of this appendix provides the amplitude values for each speed of the required parametric MCAT simulations for cant deficiencies greater than 3 inches and not more than 5 inches. Table 6 of this appendix provides the amplitude values for each speed of the required parametric MCAT simulations for cant deficiencies greater than 5 inches. The last set of simulations at the maximum cant deficiency shall be performed at 5 m.p.h. above the proposed maximum operating speed using the amplitude values in table 5 or 6 of this appendix, as appropriate, that correspond to the proposed maximum operating speed and cant deficiency. For these simulations, the value of curvature, D, shall correspond to the proposed maximum operating speed and cant deficiency. For qualification of vehicle types at speeds greater than track Class 6 speeds, the following additional simulations shall be performed:

(A) For vehicle types being qualified for track Class 7 speeds, one additional set of simulations shall be performed at 115 m.p.h. using the track Class 6 amplitude values in table 5 or 6 of this appendix, as appropriate (i.e., a 5 m.p.h. overspeed on Class 6 track) and a value of curvature, D, that corresponds to 110 m.p.h. and the proposed maximum cant deficiency.

(B) For vehicle types being qualified for track Class 8 speeds, two additional set of simulations shall be performed. The first set of simulations shall be performed at 115 m.p.h. using the track Class 6 amplitude values in table 5 or 6 of this appendix, as appropriate (i.e., a 5 m.p.h. overspeed on Class 6 track) and a value of curvature, D, that corresponds to 110 m.p.h. and the proposed maximum cant deficiency. The second set of simulations shall be performed at 130 m.p.h. using the track Class 7 amplitude values in table 5 or 6, as appropriate (i.e., a 5 m.p.h. overspeed on Class 7 track) and a value of curvature, D, that corresponds to 125 m.p.h. and the proposed maximum cant deficiency.

(C) For vehicle types being qualified for track Class 9 speeds, three additional sets of simulations shall be performed. The first set of simulations shall be performed at 115 m.p.h. using the track Class 6 amplitude values in table 5 or 6 of this appendix, as appropriate (i.e., a 5 m.p.h. overspeed on Class 6 track) and a value of curvature, D, that corresponds to 110 m.p.h. and the proposed maximum cant deficiency. The second set of simulations shall be performed at 130 m.p.h. using the track Class 7 amplitude values in table 5 or 6, as appropriate (i.e., a 5 m.p.h. overspeed on Class 7 track) and a value of curvature, D, that corresponds to 125 m.p.h. and the proposed maximum cant deficiency. The third set of simulations shall be performed at 165 m.p.h. using the track Class 8 amplitude values in table 5 or 6, as appropriate (i.e., a 5 m.p.h. overspeed on Class 8 track) and a value of curvature, D, that corresponds to 160 m.p.h. and the proposed maximum cant deficiency.

Table 5 of Appendix D to Part 213

Track Classes 6 through 9 Amplitude Parameters (in inches) for MCAT Simulations on Curved Track with Cant Deficiency > 3 and ≤ 5 Inches

		Gage 56.5"				Gage 57.0"			
		Class 6	Class 7	Class 8	Class 9	Class 6	Class 7	Class 8	Class 9
Max. Operating Speed (m.p.h.)		110	125	160	220	110	125	160	220
Max. Simulation Speed (m.p.h.)		115	130	165	225	115	130	165	225
MCAT Segments	**Parameter**	**Segment Description**				**Segment Description**			
Hunting	a_1	(b)(1)(i) [1]				(b)(1)(i) [1]			
Gage Narrowing	a_2	(b)(1)(ii)				(b)(1)(ii)			
Gage Widening	a_3	(b)(1)(iii)				(b)(1)(iii)			
Repeated Surface	a_9	(b)(1)(iv)				(b)(1)(iv)			
Repeated Alinement	a_4	(b)(1)(v)				(b)(1)(v)			
Single Surface	a_{10}, a_{11}	(b)(1)(vi)				(b)(1)(vi)			
Single Alinement	a_5, a_6	(b)(1)(vii)				(b)(1)(vii)			
Short Warp	a_{12}	(b)(1)(viii)				(b)(1)(viii)			
Combined Perturbation	a_7, a_8, a_{13}				(b)(1)(ix)				(b)(1)(ix)
		Amplitude Parameters (inches)				Amplitude Parameters (inches)			
Wavelength λ = 10ft	a_1	0.250[1]	0.250[1]	0.250[1]	0.250[1]	0.250[1]	0.250[1]	0.250[1]	0.250[1]
Wavelength λ = 20ft	a_{12}	0.625	0.563	0.500	0.375	0.625	0.563	0.500	0.375
Wavelength λ = 31ft	a_2	0.500	0.500	0.500	0.250	0.500	0.500	0.500	0.500
	a_3	0.750	0.500	0.500	0.500	0.250	0.250	0.250	0.500
	a_4	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375
	a_5	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
	a_6	0.000	0.000	0.000	0.000	0.250	0.250	0.250	0.250
	a_7				0.333				0.333
	a_8				0.000				0.083
	a_9	0.750	0.750	0.500	0.375	0.750	0.750	0.500	0.375
	a_{10}	1.000	1.000	0.750	0.500	1.000	1.000	0.750	0.500
	a_{11}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	a_{13}				0.333				0.333
Wavelength λ = 62ft	a_2	0.500	0.500	0.500	0.250	0.500	0.500	0.500	0.500
	a_3	0.750	0.500	0.500	0.500	0.250	0.250	0.250	0.250
	a_4	0.500	0.375	0.375	0.375	0.500	0.375	0.375	0.375
	a_5	0.625	0.500	0.500	0.500	0.625	0.500	0.500	0.500
	a_6	0.000	0.000	0.000	0.000	0.375	0.250	0.250	0.250
	a_7				0.333				0.333
	a_8				0.000				0.083
	a_9	0.750	0.750	0.750	0.500	0.750	0.750	0.750	0.500
	a_{10}	1.000	1.000	1.000	0.750	1.000	1.000	1.000	0.750
	a_{11}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	a_{13}				0.500				0.500
Wavelength λ = 124ft	a_2	0.500	0.500	0.500	0.250	1.000	1.000	1.000	0.750
	a_3	0.750	0.750	0.750	0.750	0.250	0.250	0.250	0.250
	a_4	1.000	0.875	0.500	0.500	1.000	0.875	0.500	0.500
	a_5	1.500	1.250	0.750	0.750	1.500	1.250	0.750	0.750
	a_6	0.750	0.500	0.000	0.000	1.250	1.000	0.500	0.500
	a_7				0.500				0.500
	a_8				0.000				0.250
	a_9	1.250	1.000	0.875	0.625	1.250	1.000	0.875	0.625
	a_{10}	1.750	1.500	1.250	1.000	1.750	1.500	1.250	1.000
	a_{11}	0.250	0.000	0.000	0.000	0.250	0.000	0.000	0.000
	a_{13}				0.667				0.667

[1] For curves <1 degree

Table 6 of Appendix D to Part 213

Track Class 6 through 9 Amplitude Parameters (in inches)

for MCAT Simulations on Curved Track with Cant Deficiency > 5 Inches

		Gage 56.5"				Gage 57.0"			
		Class 6	Class 7	Class 8	Class 9	Class 6	Class 7	Class 8	Class 9
Max. Operating Speed (m.p.h.)		110	125	160	220	110	125	160	220
Max. Simulation Speed (m.p.h.)		115	130	165	225	115	130	165	225
MCAT Segments	**Parameter**	**Segment Description**				**Segment Description**			
Hunting	a_1	(b)(1)(i) [1]				(b)(1)(i) [1]			
Gage Narrowing	a_2	(b)(1)(ii)				(b)(1)(ii)			
Gage Widening	a_3	(b)(1)(iii)				(b)(1)(iii)			
Repeated Surface	a_9	(b)(1)(iv)				(b)(1)(iv)			
Repeated Alinement	a_4	(b)(1)(v)				(b)(1)(v)			
Single Surface	a_{10}, a_{11}	(b)(1)(vi)				(b)(1)(vi)			
Single Alinement	a_5, a_6	(b)(1)(vii)				(b)(1)(vii)			
Short Warp	a_{12}	(b)(1)(viii)				(b)(1)(viii)			
Combined Perturbation	a_7, a_8, a_{13}				(b)(1)(ix)				(b)(1)(ix)
		Amplitude Parameters (inches)				**Amplitude Parameters (inches)**			
Wavelength λ = 10ft	a_1	0.250[1]	0.250[1]	0.250[1]	0.250[1]	0.250[1]	0.250[1]	0.250[1]	0.250[1]
Wavelength λ = 20ft	a_{12}	0.625	0.500	0.500[2]	0.375	0.625	0.500	0.500[2]	0.375
Wavelength λ = 31ft	a_2	0.500	0.500	0.500	0.250	0.500	0.500	0.500	0.500
	a_3	0.750	0.500	0.500	0.500	0.250	0.250	0.250	0.500
	a_4	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375
	a_5	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
	a_6	0.000	0.000	0.000	0.000	0.250	0.250	0.250	0.250
	a_7	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333
	a_8	0.000	0.000	0.000	0.000	0.083	0.083	0.083	0.083
	a_9	0.750	0.750	0.500	0.375	0.750	0.750	0.500	0.375
	a_{10}	1.000	1.000	0.750	0.500	1.000	1.000	0.750	0.500
	a_{11}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	a_{13}	0.667	0.667	0.500	0.333	0.667	0.667	0.500	0.333
Wavelength λ = 62ft	a_2	0.500	0.500	0.500	0.250	0.500	0.500	0.500	0.500
	a_3	0.750	0.500	0.500	0.500	0.250	0.250	0.250	0.250
	a_4	0.500	0.375	0.375	0.375	0.500	0.375	0.375	0.375
	a_5	0.625	0.500	0.500	0.500	0.625	0.500	0.500	0.500
	a_6	0.000	0.000	0.000	0.000	0.375	0.250	0.250	0.250
	a_7	0.417	0.333	0.333	0.333	0.417	0.333	0.333	0.333
	a_8	0.000	0.000	0.000	0.000	0.167	0.083	0.083	0.083
	a_9	0.750	0.750	0.750	0.500	0.750	0.750	0.750	0.500
	a_{10}	1.000	1.000	1.000	0.750	1.000	1.000	1.000	0.750
	a_{11}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	a_{13}	0.667	0.667	0.667	0.500	0.667	0.667	0.667	0.500
Wavelength λ = 124ft	a_2	0.500	0.500	0.500	0.250	1.000	1.000	1.000	0.750
	a_3	0.750	0.750	0.750	0.750	0.250	0.250	0.250	0.250
	a_4	1.000	0.875	0.500	0.500	1.000	0.875	0.500	0.500
	a_5	1.250	1.000	0.750	0.750	1.250	1.000	0.750	0.750
	a_6	0.500	0.250	0.000	0.000	1.000	0.750	0.500	0.500
	a_7	0.833	0.667	0.500	0.500	0.833	0.667	0.500	0.500
	a_8	0.083	0.000	0.000	0.000	0.583	0.417	0.250	0.250
	a_9	1.250	1.000	0.875	0.625	1.250	1.000	0.875	0.625
	a_{10}	1.500	1.250	1.250	1.000	1.500	1.250	1.250	1.000
	a_{11}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	a_{13}	1.000	0.833	0.833	0.667	1.000	0.833	0.833	0.667

[1] For curves <1 degree [2] 0.375 for E_u>7"

(4) *Vehicle performance on curved track Classes 1 through 5 at high cant deficiency.* For maximum vehicle speeds corresponding to track Classes 1 through 5, the MCAT segments described in paragraphs (b)(1)(ii) through (ix) of this appendix shall be used to assess vehicle performance on curved track if the proposed maximum cant deficiency is greater than 6 inches. A parametric matrix of MCAT simulations shall be performed using the following range of conditions:

(i) *Vehicle speed.* Simulations shall demonstrate that at up to 5 m.p.h. above the proposed maximum operating speed, the vehicle

shall not exceed the wheel/rail force and acceleration criteria defined in the Vehicle/Track Interaction Safety Limits table in §213.333. Simulations shall also demonstrate acceptable vehicle dynamic response at 5 m.p.h. above the proposed maximum operating speed.

(ii) *Perturbation wavelength.* For each speed, a set of two separate MCAT simulations shall be performed. In each MCAT simulation for the perturbation segments described in paragraphs (b)(1)(ii) through (vii) and paragraph (b)(1)(ix) of this appendix, every perturbation shall have the same wavelength. The following two wavelengths, λ, shall be used: 31 and 62 feet. The short warp perturbation segment described in paragraph (b)(1)(viii) of this appendix has a fixed wavelength, λ, of 20 feet.

(iii) *Track curvature.* For a speed corresponding to 5 m.p.h. above the proposed maximum operating speed, a range of curvatures shall be used to produce cant deficiency conditions ranging from 6 inches up to the maximum intended for qualification (in 1 inch increments). The value of curvature, D, shall be determined using the equation in paragraph (b)(3) of this appendix. Each curve shall contain the MCAT segments described in paragraphs (b)(1)(ii) through (ix) of this appendix and have a fixed superelevation of 6 inches.

(iv) *Amplitude parameters.* Table 7 of this appendix provides the amplitude values for the MCAT segments described in paragraphs (b)(1)(ii) through (ix) of this appendix for each speed of the required parametric MCAT simulations.

Table 7 of Appendix D to Part 213

Track Class 1 through 5 Amplitude Parameters (in inches)

for MCAT Simulations on Curved Track with Cant Deficiency > 6 Inches

		Gage 56.5"					Gage 57.0"				
		Class 1	Class 2	Class 3	Class 4	Class 5	Class 1	Class 2	Class 3	Class 4	Class 5
Max. Operating Speed (m.p.h.)		15	30	60	80	90	15	30	60	80	90
Max. Simulation Speed (m.p.h.)		20	35	65	85	95	20	35	65	85	95
MCAT Segments	**Parameter**	**Segment Description**					**Segment Description**				
Hunting	a_1										
Gage Narrowing	a_2	(b)(1)(ii)					(b)(1)(ii)				
Gage Widening	a_3	(b)(1)(iii)					(b)(1)(iii)				
Repeated Surface	a_9	(b)(1)(iv)					(b)(1)(iv)				
Repeated Alinement	a_4	(b)(1)(v)					(b)(1)(v)				
Single Surface	a_{10}, a_{11}	(b)(1)(vi)					(b)(1)(vi)				
Single Alinement	a_5, a_6	(b)(1)(vii)					(b)(1)(vii)				
Short Warp	a_{12}	(b)(1)(viii)					(b)(1)(viii)				
Combined Perturbation	a_7, a_8, a_{13}	(b)(1)(ix)					(b)(1)(ix)				
		Amplitude Parameters (inches)					**Amplitude Parameters (inches)**				
Wavelength λ = 10ft	a_1										
Wavelength λ = 20ft	a_{12}	1.000	1.000	0.875	0.875	0.750	1.000	1.000	0.875	0.875	0.750
Wavelength λ = 31ft	a_2	0.500	0.500	0.500	0.500	0.500	1.250	1.250	1.250	0.500	0.500
	a_3	1.250	1.250	1.250	0.500	0.500	0.750	0.750	0.750	0.500	0.500
	a_4	0.750	0.750	0.750	0.750	0.500	0.750	0.750	0.750	0.750	0.500
	a_5	0.750	0.750	0.750	0.750	0.500	0.750	0.750	0.750	0.750	0.500
	a_6	0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.250	0.000
	a_7	0.500	0.500	0.500	0.500	0.333	0.500	0.500	0.500	0.500	0.333
	a_8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	a_9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	a_{10}	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	a_{11}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	a_{13}	0.667	0.667	0.667	0.667	0.667	0.667	0.667	0.667	0.667	0.667
Wavelength λ = 62ft	a_2	0.500	0.500	0.500	0.500	0.500	1.250	1.250	1.250	0.500	0.500
	a_3	1.250	1.250	1.250	0.500	0.500	0.750	0.750	0.750	0.500	0.500
	a_4	1.250	1.250	1.250	0.875	0.625	1.250	1.250	1.250	0.875	0.625
	a_5	1.250	1.250	1.250	0.875	0.625	1.250	1.250	1.250	0.875	0.625
	a_6	0.000	0.000	0.000	0.375	0.125	0.500	0.500	0.500	0.375	0.125
	a_7	0.833	0.833	0.833	0.583	0.417	0.833	0.833	0.833	0.583	0.417
	a_8	0.000	0.000	0.000	0.083	0.000	0.083	0.083	0.083	0.083	0.000
	a_9	1.750	1.750	1.750	1.250	1.000	1.750	1.750	1.750	1.250	1.000
	a_{10}	1.750	1.750	1.750	1.250	1.000	1.750	1.750	1.750	1.250	1.000
	a_{11}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	a_{13}	1.167	1.167	1.167	0.833	0.667	1.167	1.167	1.167	0.833	0.667

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